J. Ethnobiol. 13(2):203–231 Winter 1993

HOPI CROP DIVERSITY AND CHANGE

DANIELA SOLERI
and
DAVID A. CLEVELAND
Center for People, Food, and Environment
344 South Third Ave.
Tucson, AZ 85701

ABSTRACT.—There is increasing interest in conserving indigenous crop genetic diversity *ex situ* as a vital resource for industrial agriculture. However, crop diversity is also important for conserving indigenously based, small-scale agriculture and the farm communities which practice it. Conservation of these resources may best be accomplished, therefore, by ensuring their survival *in situ* as part of local farming communities like the Hopi. The Hopi are foremost among Native American farmers in the United States in retaining their indigenous agriculture and folk crop varieties (FVs), yet little is known about the dynamics of change and persistence in their crop repertoires. The purpose of our research was to investigate agricultural crop diversity in the form of individual Hopi farmers' crop repertoires, to establish the relative importance of Hopi FVs and non-Hopi crop varieties in those repertoires, and to explore the reasons for change or persistence in these repertoires. We report data from a 1989 survey of a small (n = 50), opportunistic sample of Hopi farmers and discuss the dynamics of change based on cross-sectional comparisons of the data on crop variety distribution, on farmers' answers to questions about change in their crop repertoires, and on the limited comparisons possible with a 1935 survey of Hopi seed sources. Because ours is a small, nonprobabilistic sample it is not possible to make valid extrapolations to Hopi farmers in general. It is, however, possible for us to suggest some hypotheses about crop diversity and change based on our results and illustrated with examples. The fate of each FV depends on the unique combination of the biophysical and sociocultural environment of that FV. FVs will tend to be lost when changes in the local biophysical and/or sociocultural environment reduce the importance of the FVs' adaptation. FVs will tend to be retained when the biophysical and/or sociocultural environment remains the same, or changes in ways that increase the importance of the FVs' adaptation. When changes in the biophysical and sociocultural environments make loss of FVs possible, the availability of seeds and alternative food or other products will become important.

RESUMEN.—Existe un creciente interés en conservar la diversidad genética de los cultivos indígenas *ex situ* como un recurso vital para la industria agrícola. Sin embargo, la diversidad de cultivos es importante también para conservar la agricultura indígena de pequeña escala y las comunidades campesinas que la practican. La conservación de estos recursos puede ser mejor lograda, por lo tanto, asegurando su sobrevivencia *in situ* como parte de comunidades agrícolas locales como los Hopi. Los Hopi sobresalen entre los agricultores indios en los Estados Unidos de Norteamérica en cuanto a retener su agricultura indígena y sus variedades criollas de cultivos, pero poco se conoce de la dinámica de cambio y persistencia en sus repertorios de cultivos. El propósito de nuestra labor fue investigar la diversidad de cultivos en la forma de repertorios de cultivos de algunos agricultores. Hopi individualmente, establecer la importancia relativa de las variedades criollas y las variedades no Hopis en esos repertorios, y explorar las razones para el cambio o la persistencia en dichos repertorios. Reportamos aquí los datos obtenidos en un estudio realizado en 1989 con una muestra pequeña (n = 50) y oportunista de agricultores Hopi, y discutimos la dinámica del cambio en base a comparaciones internas de los datos sobre distribución de variedades de cultivos, en base a las respuestas de los agricultores a preguntas sobre el cambio en sus repertorios de cultivos, y en base a las limitadas comparaciones posibles con un estudio hecho en 1935 sobre fuentes de semillas Hopis. Dado que la nuestra es una muestra pequeña no probabilística, no es posible hacer extrapolaciones válidas para los agricultores Hopis en general. Sí es posible, no obstante, que sugiramos algunas hipotesis sobre la diversidad y el cambio de los cultivos en base a nuestros resultados, ilustradas con ejemplos. El destino de cada variedad criolla depende de la combinación única del ambiente biofísico y sociocultural de tal variedad. Las variedades criollas tenderán a perderse cuando los cambios en el ambiente biofísico y/o sociocultural reducen la importancia de la adaptación de la variedad. Las variedades criollas tenderán a retenerse cuando el ambiente biofísico y/o sociocultural permanece igual, o cambia en forma tal que aumenta la importancia de la adaptación de la variedad. Cuando los cambios en los ambientes biofísicos y socioculturales hacen posible la pérdida de variedades criollas, la disponibilidad de semillas y alimento u otros productos alternativos adquirirá importancia.

RÉSUMÉ.—La conservation de la diversité génétique *ex situ* des plantes indigènes comme ressource vitale pour l'agriculture industrielle prend une importance grandissante. Toute fois, la continuité des pratiques traditionnelles ou indigènes des petites fermes agricoles demeure importante pour la conservation de la diversité génétique pour les populations pratiquant ce genre d'agriculture. Par conséquent, les ressources agricoles peuvent être mieux conservées en assurant leur survie *in situ* par une production traditionnelle à l'example des Hopis. La tribue Hopi est un groupe parmis les indiens Americains qui pratiquent une agriculture traditionnelle depuis des générations, cependant, peu d'information existe concernant les dynamiques de changements et la persistence du répertoire agricole des Hopis. Le but de notre recherche était d'investiguer la diversité génétique du matériel végétal des agriculteurs individuels Hopis, et d'établir l'importance relative des plantes locales et introduites, ainsi que d'explorer les raisons qui ont conduit au changement ou à la persistence du répertoire agricole des Hopis. Nous reportons ici les données d'un sondage de 50 agriculteurs fait en 1989 et discutons la dynamique de ces changements en se basant sur des comparaisons transversales des données sur la distributions des plantes cultivées, les réponses des paysans aux questionnaires concernant les modifications de leur répertoire agricole, et les comparaisons limitées de nos résultats avec ceux d'un sondage fait en 1935 sur les ressources en semences des Hopis. Nos échantillons de sondages sont petits en nombre, donc, il serait impossible d'extrapoler en général sur l'agriculture des Hopis. Il est possible cependant de suggérer des hypothèses concernant la diversité et les changements dans l'agriculture Hopis en se basant sur nos résultats, accompagnés d'examples illustratifs. Le destin de chaque variété locale cultivée dépend d'une combinaison unique de facteurs biophysiques et socioculturels se rapportant à la variété cultivée en question. Les variétés locales ont tendance à disparaître quand les changements dans l'environment local biophysique ainsi que socioculturel entraînent la réduction de leur importance adaptive. Les variétés locales ont tendance à être retenues au sein du système de production si les facteurs biophysiques ou socioculturels restent identiques, ou changent d'une manière à rendre leur adaptation plus importante. Quand ces facteurs produisent des conditions favorables à la perte d'une variété locale, la recherche des semences, plantes ou produits de substitution devient importante.

INTRODUCTION

There is growing evidence of an increasing rate of loss of cultural and biological diversity, of unprecedented environmental destruction, and of the instability and excessive cost of industrial agriculture systems (Brown, L. 1990; Ehrlich and Wilson 1991; NRC 1989). One response to the threat to agricultural diversity has been increasing interest in indigenous crop genetic resources (Keystone 1990, 1991; Plucknett et al. 1987:3–18). While most of this interest has been in conserving diversity *ex situ* as a resource for industrial agriculture, crop diversity is also important for conserving indigenously based, small-scale agriculture and the farm communities which practice it. There is increasing realization that different cultures and different environments make diverse demands of their farming systems which go beyond simple production (Cleveland and Soleri 1991:285–295). It is therefore important to understand the relationship between biological and cultural diversity in agriculture, including the ways in which both new and old crops and crop varieties fit the cultural and environmental needs of a society and its farming system.

Crops are one form in which diversity can be expressed in an agricultural system, and this diversity can occur at different levels. It is frequently the case that compared with "modern" crop varieties (MVs) produced for use in industrial agriculture, the folk crop varieties (FVs, also referred to as landraces or traditional varieties) of indigenous or traditional agriculture contain substantial genetic diversity (Frankel and Soulé 1981:179, 201–202). This diversity may be present within individual plants (heterozygosity), among individuals within a heterogeneous variety, among varieties within a species, or in the large number of species and varieties often grown by indigenous farmers.

In general, greater diversity in agriculture appears to be associated with greater stability, i.e., less variation in yield from year to year. Although not a closed issue, the contribution of diversity to stability in agricultural systems is widely supported by evidence in agricultural economics (Anderson and Hazell 1989; Barker et al. 1981), plant breeding (Borojevic 1990:333–334; Weitzien and Fischbeck 1990), and agroecology (Pimentel et al. 1992; Thurston 1992:193–211). Theoretically, therefore, a major benefit provided to low resource farmers by diverse, locally adapted crop varieties, like many FVs, and the low-input cropping systems of which they are a part, is a reduced risk of crop failure due to environmental variation or unavailability of outside inputs, as well as a sustainable source of seeds for future plantings (Clawson 1985; Soleri et al. 1991; Richards 1986:134–138; Thurston 1992:193–211). Industrialized agriculture usually lacks the crop genetic and management diversity of indigenous systems. This relative lack of diversity often means that in the event of a shortage of inputs, industrial systems are more vulnerable to environmental conditions and therefore experience more yield variability (Anderson and Hazell 1989; Barker et al. 1981).

Efforts to conserve crop genetic resources have increased significantly in the last several decades with the growing recognition of their value for all agricultural systems, their loss due to replacement of FVs by MVs, and the loss of habitat of wild and weedy crop relatives (Wilkes 1989). This conservation effort has focused almost exclusively on collecting and saving these resources *ex situ* in gene banks (e.g., Plucknett et al. 1987:3–18). Recently, *in situ* conservation of crop genetic resources has been advocated as an essential complement to *ex situ* conservation (Altieri 1988; Brush 1989, 1991; Soleri et al. 1991; Oldfield and Alcorn 1987; Cooper et al. 1992).

Some of the biological benefits of *in situ* over *ex situ* conservation are maintaining the evolution of the crop variety under human and environmental selection, and avoiding loss of valuable alleles due to inadequate sampling strategy or sample size while collecting (genetic drift) or novel selection pressures during *ex situ* seed generation (genetic shift) (Wilkes 1989). However, for many, even more important benefits of *in situ* conservation are greater local access to and control of crop genetic resources and farming systems and survival of the communities supported by those farming systems (Altieri 1988; Cooper et al. 1992; Oldfield and Alcorn 1987). Ensuring that *in situ* conservation is in fact a reflection of local control and not external decision-making will be difficult. However, the potential benefits of *in situ* conservation can only be realized if this strategy makes sense to the farmers and gardeners who are participating. Farming communities that have maintained some of their FVs, especially in circumstances where seed for industrial MVs is readily available, are examples of indigenous *in situ* conservation. Identifying crop repertoires of such farmers, and understanding why and how these communities maintain their traditional crop genetic resources will provide insights valuable for supporting *in situ* conservation and for creating sustainable agriculture based on indigenous knowledge.

The Hopi are foremost among Native American farmers in the United States in retaining their indigenous agriculture and FVs, yet little is known about the dynamics of change and persistence in their crop repertoires. The scanty information available to outsiders is not adequate to address this question. The work of Whiting, who directed a survey of Hopi seeds in 1935 and published an ethnobotany of the Hopi, provides examples of the difficulty of reaching meaningful conclusions because of lack of data and the complexity of crop repertoire dynamics. In fact, many of Whiting's generalizations appear to be contradictory.

For example, on the one hand Whiting stated that "when it comes to seed, the Hopi will try anything once," and as a result only "a few" Hopi crops are "ancient," most of them having "been discarded in favor of other varieties which are easier to grow, yield better, and have better flavoring or are more easily prepared" (Whiting 1936:3). On the other hand, however, Whiting also stated that the results of trying new varieties "are often failures," and many crops grown by Hopi are "remarkably adapted to his particular environment, more so than those of the white man" (1936:3). In his Hopi ethnobotany Whiting compared contemporary Hopi varieties with those noted by Stephen (1936:353–354) and wrote that "Considering the intense interest of the Hopi in new varieties of crop plants and their numerous introductions and experiments it is surprising that Hopi agriculture is as stable as it is. . . . This stability is due, in part, to the fact that new crops are often abandoned almost as quickly as they are introduced" (Whiting 1939:11).

Obviously, to understand the many different factors which determine changes in crop repertoires, and which may differ for each particular variety, it is necessary to have the data required first to frame, and then to test, specific hypotheses. The purpose of our research was to investigate agricultural crop diversity in the form of individual Hopi farmers' crop repertoires, to establish the relative importance of Hopi FVs and non-Hopi crop varieties in those repertoires, and to generate hypotheses to explain change or persistence in these repertoires. We report data from a survey of a small, nonprobability sample of Hopi farmers and discuss the dynamics of change based on cross-sectional comparisons of the data on crop variety distribution, on farmers' answers to questions about change in their crop repertoires, and on the limited comparisons possible with the 1935 survey of Hopi seed sources directed by Whiting.

METHODS

Fieldwork was done between late summer 1988 and fall 1989. Hopis have been subjected to so much disturbance and questioning by outsiders for so many years that they are often understandably reluctant to spend much time talking with researchers. Because of this, our goal was not a probability sample, but rather to talk with some farmers in each village we visited by going from door-to-door, and by using referrals. This method was used by Carter (1945:11) in his survey of Native American crops. Because ours was a small, nonprobability sample, it is not possible to make valid extrapolations to Hopi farmers in general. It is, however, possible for us to suggest some hypotheses about crop diversity and change based on our results.

Farmers in Hotevilla, Bacavi, Kykotsmovi, Old Oraibi, and Shungopovi were contacted by Soleri and Cleveland in door-to-door visits (Fig. 1). Seven farmers were also interviewed by Gary Nabhan in Upper and Lower Moenkopi, the irrigated Hopi villages ajoining Tuba City. Over 60 farmers were interviewed, but only data from 50 of those were considered complete enough to be used in this report.

The majority of farmers interviewed were older, retired men. While men are usually responsible for the field work, care of the seeds from harvest until the next planting is the responsibility of women, and so in most cases farming is a collaboration between men and women. A husband-and-wife farming team often answered our questions together, discussing, confirming, or contradicting each other's responses. In a number of cases younger men would respond together with their mothers, or their mothers-in-law. One female farmer was also interviewed independently.

It seems very possible that this age distribution may have resulted in unrepresentatively large crop repertoires and a high proportion of Hopi varieties. Reasons for this include that the older men making up the majority of the sample have grown up and lived during a time when Hopi farming and ceremonial traditions were much stronger than they are today; they have more farming experience than younger Hopis; and they have more time to farm than do youn-

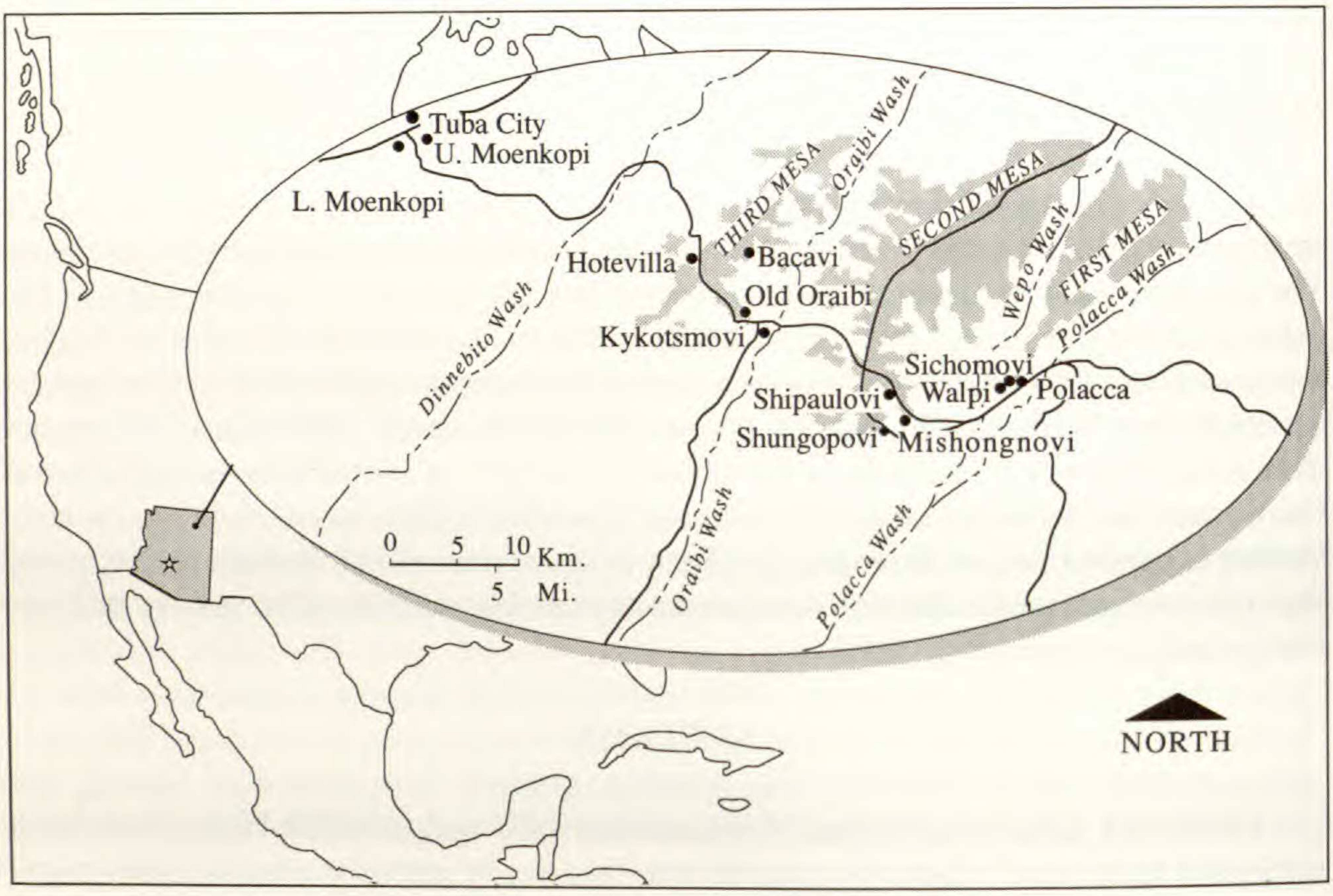

FIG. 1—Location of the study area in Arizona, U.S.A., showing the three Hopi mesas, the washes, and the Hopi villages mentioned in the text.

ger Hopis engaged in or seeking full time wage work. On the other hand, as these men get very old their farming decreases, especially if their children or their children's spouses do not farm. When data on corn varieties grown are grouped by broad, estimated age categories, households with older, male farmers have a higher average number of varieties: farmers less than 30 years old (n = 3), 5.0 varieties; farmers 30–60 years (n = 12), 6.2 varieties; and farmers over 60 years (n = 30), 6.8 varieties.[1]

Another potential source of misrepresentation was the tendency for people to assume that we wanted to, or should, only talk with the "best" farmers. We tried to avoid this problem by going door-to-door, not just using referrals. However, we suspect that some Hopis may simply have disqualified themselves because they did not feel that their farming activity or experience was adequate.

The interview schedule was a reference list of Hopi crop varieties with Hopi names based on Whiting's ethnobotany (1939), which he in turn based on the 1935 seed source survey (Whiting 1935, 1936, 1937), although he obviously used other sources. The names were written phonetically to assist interviewers. Using the schedule as an "ethnographic interview guide" is an approach currently being used by others for participatory research among Native American communities (Reidhead 1989). We did not attempt to identify the specific varieties of non-Hopi crops, since farmers often did not know the specific varieties, for example of "bush beans" or "sweet corn."

Based on this schedule we asked farmers "What crops do you grow?" from each crop category (corn, lima beans, melons, and so on). We purposefully decided not to ask only what crops were being grown during the current year, as it appears may have been done in the 1935 survey, since farmers do not grow all of their crops each year and thus would not have mentioned many of the crops in their repertoires. We wanted to identify the crop varieties these farmers grow regularly and which they themselves consider to be a part of their repertoires. Thus the data collected were lists of crop varieties in farmers' current crop repertoires according to the farmers themselves.

What is a FV?—Determining which crops should be considered "Hopi" FVs and which should not was an important but difficult problem for our work. It reflects the larger problem of defining what constitutes a FV in studies of indigenous farmer management of crop genetic resources. The problem becomes even more complicated when trying to distinguish between a "Hopi" and "non-Hopi" variety whose fruits or seeds are morphologically very similar. Differences, if they exist, are in genotype, plant morphology, agronomic characteristics, or harvest quality, none of which could be consistently observed in this survey.

While frustrating for research which is inclined to place all crops into neat, discrete categories, this dilemma is an excellent reminder of the fluidity of living, nonindustrial farming systems in which human and environmental selection of crops is continuous. Perhaps because of these difficulties some researchers considering this problem have defined FVs as representing a management strategy, not genetic composition (Brush et al. 1988).

However, this neglects the effect of deliberate human selection, management strategies, and environmental factors on crop evolution, which is widely recognized by plant geneticists as the basis for FVs (Harlan 1992:127–128). The question is, do these varieties exhibit, or have the potential to exhibit, phenotypic differences which reflect significant genotypic differences present as a result of selection by local farmers and the local environment, or are they relatively recent introductions which have not been so influenced?

This is a difficult question to answer because a cutoff point will necessarily be arbitrary, and so there will be ambiguous cases. In this paper we use the imprecise but widely used definition of a FV (or landrace) as "geographically or ecologically distinctive populations which are conspicuously diverse in their genetic composition both between populations and within them . . . which evolved under cultivation" (Brown, A.D.H. 1978:145), and which are the product of local selection. The key words in this definition are "distinctive" and "conspicuously," which again of course imply an arbitrary judgement.

We assume that the named Hopi varieties reported by the farmers are FVs. However, we did not collect voucher specimens from farmers. We did look at and discuss seed, fruit, or plants of the crops whenever possible, and some farmers gave us samples which we used for our own reference. Some non-Hopi varieties were often further differentiated as "commercial," i.e., purchased. We use the term "commercial" to indicate non-Hopi varieties generally obtained commercially as opposed to non-Hopi varieties obtained from other sources such as other Native American groups. As previously noted, the names of non-Hopi varieties were much less precisely known by Hopi farmers, and varieties were often lumped together, and we did not differentiate them.

HOPI AGRICULTURE AND CULTURE

Archeological evidence suggests that the Hopi Native Americans or their direct ancestors have lived for well over 1000 years in the area that is now the Hopi Reservation in northern Arizona (Brew 1979). Hopi agriculture, including FVs, appears to be the unique result of biophysical and sociocultural influences. It is probably one of the richest and most persistant of all Native American agricultures in the United States today, and yet remains relatively unknown to the outside world. Changes in Hopi agriculture during the last 100 years are dominated by reductions in areas farmed (Prevost et al. 1984) and proportion of people farming (Kennard 1979).

The biophysical environment.—The Hopi environment would challenge any farmer. Nonetheless, Hopi farmers and gardeners have developed an agricultural system which, through careful observation and skillful management, has sustained their communities for well over 1000 years.

The Hopi Indian Reservation is located in the high desert of northeastern Arizona, where the growing season between freezing temperatures is short, 120–160 days, depending on the location. Frequent drying winds, especially at the beginning of the growing season, and high summer temperatures produce high rates of evapotranspiration. These conditions, along with the lack of surface water and low and variable annual precipitation, makes water the resource most limiting to agricultural production. The topographical and geological features of the Hopi lands and those north of them have a major effect on the availability of water to Hopi agriculture and communities. The northeastern half of the existing reservation is the southern escarpment of Black Mesa, which rises to an elevation of approximately 2400 m.

Three mesas run southwest from Black Mesa, separated by four washes from east to west: Polacca, Wepo, Oraibi, and Dinnebito (Fig. 1). The mesas, now referred to as First, Second, and Third, from east to west, are over 1,830 m high at their southern points, where most of the Hopi villages are located. Although the village sites are rocky promontories with little or no vegetation, juniper and piñon pines dominate the higher areas of the reservation. In between the mesas and to the south of them, the washes spread out into flat, wide, undulating lowlands where wild grasses and small shrubs grow (Bradfield 1971:13; Prevost et al. 1984).

Under the USDA Land Capability Classification System, soils of the Hopi Reservation (classes VI and VII) are considered unsuitable for cultivation and appropriate for only moderate to limited grazing (Brady 1974:347–350; Prevost et al. 1984). Four soil types dominate the cultivated areas on the reservation: (1) a sand layer over loam in alluvial fans, (2) loam soils in seasonal water courses, (3) sandy soils in dunes and often over seeps, and (4) clayey soils in irrigated terraced garden beds (Hack 1942:36).

The southern, lower part of the reservation, where most agriculture occurs, receives an annual average of 15–23 cm of precipitation (Prevost et al. 1984). This precipitation can be highly variable within a marked seasonal pattern of summer rains coming between mid-July and mid-September, and rain and snow occurring primarily from January through April. May and June are the driest months and are accompanied by strong winds.

The mesas on the reservation, and Black Mesa to its north, are composed of a permeable Mesa Verde sandstone layer overlying an impermeable layer of Mancos shale which slopes down as it runs south into the Hopi mesas (Bradfield 1971:7–9). Water from snow and rain falling north of Hopi percolates through the sandstone layer, is trapped on top of the shale, and follows its downward and southerly path until reaching the mesas. There the water may seep from the mesa sides, running under a layer of wind blown sand and moistening the heavier soil underneath. These seeps are where fruit trees, melons, squash, gourds, and beans are planted. Springs also occur and provide both drinking water and water for irrigating nearby terraced gardens.

Field production not only benefits from direct rainfall, but from spreading of runoff from summer rains, and from water stored in the soil from winter precipitation. Fields are traditionally planted by hand using a wooden or steel planting stick to dig a planting hole down through the sand and into the moist soil beneath. Planting depth increases during the course of the spring-summer planting season to accommodate rising soil temperatures and receding soil moisture. For corn this can mean a planting depth of over 25 cm, and Hopi FVs appear to be uniquely selected for this environment and planting practice (Bradfield 1971; Collins 1914a, 1914b). Many farmers now use tractors for cultivation and, with equipment especially adapted to place seed deeply, for planting, although they recognize that unlike hand planting this practice cannot adjust to variation in moisture within fields.

An early planting of corn is sometimes done in April, especially in fields which are known to have warm microclimates. Sweet corn and some early corn varieties like yellow and greasy hair are planted then in hopes of an early harvest in time for the ***Niman***,[2] or Home Dance ceremony, in July. The main planting of corn, beans, squash, melons, and gourds is in late May. Some crops may also be planted in July such as sweet corn and Hopi string beans which are both considered relatively fast (i.e., have a short time from planting to maturity).

Society, culture, and agriculture.—Today approximately 7,000 Hopis live on the reservation (Arizona State Data Center 1992) in 11 villages and another approximately 2,000 in Upper and Lower Moenkopi, which are not on the reservation according to boundary lines currently recognized by the Federal government. The Hopi Tribe estimates the annual population growth rate between 1970 and 1982 at 3%, and at about 2% from 1982–1986 (Hopi Tribe 1987).

The crops now grown by Hopi farmers are one point in a continually changing Hopi crop repertoire. Hopi have acquired their crops from different sources since they first began farming. A few are endemic wild or semidomesticated plants of the Hopi area, e.g., ***nanakopsi*** (Whiting 1939:16–17), while others were borrowed from nearby groups, e.g., tepary beans. Many of the most important crops were domesticated in Mesoamerica but were introduced into the Hopi area very early, e.g., corn, beans, and squash (Ford 1981). Many new crops were introduced from Eurasia and Africa by the Spanish, e.g., watermelon, peaches, and apricots, or from Mexico, e.g., chili peppers. Undoubtedly there was much exchange of crops and crop varieties in prehistoric times. Like most farmers, Hopi are eager to try new seed, and there are historic records of borrowing from other Indian tribes, Mormon settlers, traders, and others (Whiting 1939:8–11). For example, a drought in 1864 "scattered temporarily" many Hopi and they returned "bringing new varieties of corn with them," and Hopis also obtained seed in 1915 at the first San Diego Exposition from other farmers (1936:3). "So it goes—traders, the Indian Agency, schools, friends—are all potential sources of seed. The Hopi farmers have discovered the mail order seed houses and the nurseries of Denver and Phoenix" (Whiting 1936:3). The crop varieties that become established in the Hopi crop repertoire are those that show promise, but are subsequently selected by the natural environment and people according to biophysical and sociocultural criteria, and thus become FVs.

Hopi ceremonial life is closely integrated with agriculture and the Hopi trace their farming tradition to their beginnings as a people. At the Creator's request they chose their varieties of corn and thus chose to be farmers, in contrast to the Apaches and Paiute who chose to be hunters and gatherers (Nequatewa 1967:30–31). As Frigout (1979:564) noted, "in a sense, all Hopi life is based on the ceremonies, which assure vital equilibrium, both social and individual, and conciliate the supernatural powers in order to obtain rain, good harvests, good health, and peace." Indeed, "rain is the most common request in Hopi prayer" (Heib 1979:580).

The annual Hopi ceremonial cycle, assisted for half of the year by the ***Kachinas*** or spirits, requires active year-round participation by the Hopi people. Although all villages perform some ceremonial activities, since the early 1970s only Shungopovi has continued to perform the full ceremonial cycle (Frigout 1979). Some Hopi interviewed in 1989 expressed concern over the future of the ceremonies in their village due to lack of interest among young people.

Agricultural products, especially from diverse traditional corn varieties, are essential for participation in the rich Hopi ceremonial life. Sponsorship of ceremonial and social dances and contributions of traditional food and other goods required for participation in these activities appear to help reinforce community ties, cooperation, and redistribution of wealth within communities (Kennard 1979). The emphasis is on harmony and cooperation, and disharmony and lack of participation are seen as the cause of many problems, such as poor rains and harvests. The cultural value of agriculture and FVs is an important reason for the continued interest in agriculture among Hopis (Kennard 1979; Prevost et al. 1984), even though many other forces work in the opposite direction.

Penetration of the market economy into the Hopi communities has discouraged food production in favor of income generating work, yet today such work is in short supply. Older Hopis talk frequently of how their ceremonies, agriculture, and ultimately Hopi culture are falling victim to the pursuit of the "almighty dollar." For young and middle-aged Hopis living on the reservation, finding work, especially rewarding work, is extremely difficult because their options are almost entirely limited to working for tribal or federal agencies or craft production for the tourist trade. The 1990 US Census found a 27% unemployment rate on the reservation with over 48% of the population living below the poverty line (Arizona State Data Center 1992). Among the unemployed, drug abuse exacerbates economic and social problems. For those who are working, farming and

TABLE 1.—Farmers growing Hopi and non-Hopi crop varieties.[1] Number of farmers interviewed = 50.

Crop category	Number of farmers growing	Growing only Hopi varieties %	(no.)	Growing only non-Hopi vars. %	(no.)	Growing both Hopi & non-Hopi vars. %	(no.)
Corn	50	48%	(24)	0%	(0)	52%	(26)
Lima beans	42	86%	(36)	0%	(0)	14%	(6)
String beans	40	48%	(19)	7%	(3)[2]	45%	(18)
Field beans	40	45%	(18)	10%	(4)	23%	(9)
Tepary beans	18	94%	(17)	6%	(1)	0%	(0)
Squash	39	49%	(19)	8%	(3)	44%	(17)
Watermelons	43	54%	(23)	7%	(3)	40%	(17)
Melons	36	56%	(20)	25%	(9)	19%	(7)
Gourds	30	100%	(30)[3]	0%	(0)	0%	(0)
Sunflower	8	50%	(4)	50%	(4)	0%	(0)
Fruit trees	36	64%	(23)	6%	(2)	31%	(11)
Garden vegetables	26	0%	(0)	92%	(24)	8%	(2)

[1]Does not include self-seeded crops and seeds donated by NS/S; totals may exceed 100% due to rounding.

[2]Grown in gardens only.

[3]One farmer is growing Hopi *and* a gourd from a New Mexico Pueblo.

ceremonial activities must be fit in around work schedules. One result of these sociocultural changes, and accompanying environmental problems, has been a 40% reduction in cultivated area on the reservation between 1950 and 1982 (Prevost et al. 1984), and a reduction in the proportion of people farming (Kennard 1979). Many older men and women in our survey commented on this, saying that Hopi farming may be dying out with their generation.

RESULTS: FARMER CROP REPERTOIRES IN 1989

As shown in Table 1, Hopi FVs accounted for more than half the varieties in farmers' crop repertoires in 1989 with the exception of sunflowers and garden vegetables. However, in some crop categories dominated by Hopi FVs extensive farmer experimentation with commercial varieties is occurring.

Corn.—Corn *(Zea mays)* (Table 2) is the central crop in Hopi farmers' repertoires and was grown by all of the farmers interviewed for this survey. A total of 17 Hopi varieties were reported grown. ***Supai*** corn, named for seed markings which resemble Havasupai chin markings, is considered a FV by Hopi farmers. In addition there were five non-Hopi varieties: commercial sweet corn and commercial popcorn (these may include more than one variety), Pueblo blue corn, a "red corn from India," and a "giant field corn from a Vietnamese friend in California." It is worth noting that according to the farmers growing them, the last two varieties were experiments and therefore may not remain in their repertoires for long.

TABLE 2.—Farmers growing corn varieties. Varieties considered Hopi unless otherwise indicated.

Variety		% Farmers (n = 50)	Variety		% Farmers (n = 50)
Blues		100%	***Supai*/chinmark *(koninqua'ö)***		44%
"Standard" blue ***(sakwaqa'ö)***	82%		Greasy hair ***(wiqtö)***		36%
Hard blue ***(huruskwapu)***	10%		***Kokoma***		24%
Gray blue ***(maasiqa'ö)***	24%		Speckled/owl ***(avatsa)***		12%
Pueblo blue[1] ***(neneng-qa'ö, Hopoqa'ö?)***	4%		Pink ***(palatspipi)***		6%
Blue/***kokoma*** mixture	12%		Commercial popcorn[1]		4%
White ***(qötsaqa'ö)***		96%	Miscellaneous		12%
Yellow ***(takuri)***		70%	Hopi beige ***(qöyaqa'ö?)***	1%	
Hopi sweet ***(tawaktsi)***		64%	sweet pink	1%	
Red ***(palaqa'ö)***		62%	quilt ***(tavupqa'ö?)***	1%	
Commercial sweet[1] ***(Pahaana tawaktsi)***		52%	small white	1%	
			red corn from India[1]	1%	
			field type from friend in California[1]	1%	

[1]Non-Hopi variety or varieties.

However, commercial sweet corn seems to have become established in Hopi crop repertoires, with 50% of the sample growing it. Pueblo blue corn is considered to be a non-Hopi variety by the two farmers growing it, but appears to be an enduring part of the Hopi crop repertoire, and may be reborrowed at intervals from various Rio Grande Pueblos.

The mean number of corn varieties grown was 6.3, ranging from a high of 11 to a low of 2 varieties. Twenty-four of the farmers (48%) grow only Hopi corn varieties. For 22 of the remaining 26 farmers interviewed, the only non-Hopi corn they grow is commercial sweet corn. The other four grow another commercial corn variety in addition to commercial sweet corn. There may be more than one white corn variety, as Whiting (1939:67) found, though the farmers we talked with did not identify them.

Beans.—Hopi FVs of beans grown in 1989 included four lima *(Phaseolus lunatus),* three string *(P. vulgaris),* seven field *(P. vulgaris),* and two tepary *(P. acutifolia)* bean varieties. Commercial varieties of lima, string, and field beans were also grown. Although not currently grown, several farmers recalled an "old type" of large bean which may be the scarlet runner bean *(P. coccineus)* (Table 3). Whiting (1939:81) stated that this is "occasionally raised by the Hopi," but this variety is not listed in the 1935 seed source survey forms.[3]

Cucurbitaceae.—Farmers were growing three Hopi FVS and six non-Hopi varieties of squash (*Cucurbita* spp.). The two species of squash listed by Whiting (1939:93) as being grown in the 1930s were also present in 1989 (Table 4). However, based on

TABLE 3.—Farmers growing lima bean, string bean, field bean, and tepary bean varieties. Varieties considered Hopi unless otherwise indicated.

Variety	% Farmers (n = 50)	Variety	% Farmers (n = 50)
Lima beans		Field beans	
Yellow ***(sikya hatiko)***	38%	Yellow ***(sikya mori)***	52%
Gray ***(maasi hatiko)***	76%	Pinto ***(Kastiil mori)***	32%
White[2] ***(qöötsa hatiko)***	48%	Commercial pinto[1]	18%
Red[2] ***(pala hatiko)***	34%	Pink ***(pala mori)***	20%
Commercial "baby"[1] ***(tsatsaymori)***	6%	Anasazi analogue ***(povo'khoi-mo'ri, woka'smori)***	6%
		Grease ***(wi mori)***	4%
String beans		Rotten ***(peekya mori)***	4%
Purple ***(qöma'fva'pu)***	56%	Black? ***(qömaf'mori)***	4%
White ***(qötca'va'pu)***	40%	Commercial bush[1]	4%
Red ***(pala'va'pu)***	28%		
Commercial[1,3]	42%	Tepary beans	
		White tepary ***(qööts tsatsaymori)***	30%
		Black tepary ***(qömaf tsatsaymori)***	6%

[1]Non-Hopi variety or varieties.

[2]Morphologically similar to commercially available variety, therefore possible non-Hopi contribution to the genepool.

[3]Includes green and yellow, pole and bush beans; only two of the 21 farmers growing non-Hopi string beans grow them without irrigation, the rest are grown under irrigation, either in gardens or in Moenkopi.

samples of fruit and seeds seen during this survey, it appears that ***Hopipatnga*** was mistakenly classified in the *Ethnobotany of the Hopi* (Whiting 1939) as *C. moschata,* when it is instead *C. argyrosperma* (formerly *C. mixta*). These squash can grow to be quite large with thick, hard shells which give them a long storage life. The shells can be made into a musical instrument ***(rukunpi)*** used in the ***Niman*** ceremony. They are also used as vessels, and the ground seeds are used in ***Kachina*** face paint, according to several farmers we spoke to.

Farmers were growing both red and yellow varieties of Hopi, and red and yellow varieties of commercial, watermelons *(Citrullus vulgaris)* (Table 4). Crushed watermelon seeds are used to lubricate stones on which ***piki*** (traditional, wafer-thin cornbread) is baked. An important characteristic of traditional watermelon varieties grown by Hopi farmers was their storage life. These small, round water-melons could be kept in a cool, dry corner of the house without spoiling until as late as May of the following year, as was the case in one house we visited. Whiting mentions the disillusionment of Hopis with the poor keeping qualities of the new varieties they experimented with (Whiting 1939:92), and several farmers mentioned this to us as well.

TABLE 4.—Farmers growing Cucurbitaceae varieties. Varieties considered Hopi unless otherwise indicated.

Variety	% Farmers (n varies)	Variety	% Farmers (n varies)
Squash (n = 50)		Melons (n = 49)	
Hopipatnga *(Cucurbita agyrosperma)*	64%	Hopi casava ***(kasaava)***	25%
		Commercial casava[1]	22%
Momonvatnga[2] *(C. maxima)*	34%	Hopi cantelope ***(melooni)***	20%
Gray[3]	2%	Commercial cantelope[1]	10%
Navajo gray[1,3]	2%	Hopi muskmelon ***(melooni)***	27%
Commercial zucchini[1,4]	22%	Commercial muskmelon[1]	8%
Commercial yellow[1,5]	10%	Misc. Hopi melons[9] ***(melooni)***	16%
Commercial jack-o'-lantern[1]	8%		
Commercial scalloped[1,6]	4%	Misc. commercial melons[1,9]	16%
Commercial banana[1,7]	2%		
		Gourds (n = 49)	
Watermelons (n = 49)		Rattle	53%
Hopi red[8] ***(kawayvatnga)***	65%	Dipper	16%
Commercial red[1,8]	31%	Dipper[1,9]	2%
Hopi yellow ***(sikyavatnga)***	57%	Bilobal	18%
Commercial yellow[1,8]	12%	Horn	8%
		Miscellaneous gourds[10]	6%

[1]Non-Hopi variety or varieties.

[2]Old type, but also available from commercial seed sources.

[3]Not clear if these different, both at Hotevilla.

[4]Five of the 11 farmers grew this in gardens.

[5]Two of the five farmers grew this in gardens.

[6]One of the two farmers grew this in gardens.

[7]Grown in gardens.

[8]More than one variety.

[9]From New Mexico Pueblos.

[10]Catch-all categories used when distinction between different varieties was not or could not be made.

Three varieties of Hopi melon and three commercial varieties were grown in 1989. Confusion about, and mixing of, various *Cucumis melo* varieties need to be taken into account when considering the findings in Table 4. The "miscellaneous" category for both Hopi and commercial melons reflects some of this confusion. Whiting (1939:93) also mentions the difficulty of categorizing these melon varieties.

Over half of the farmers grew rattle gourds, and several farmers grew other types of gourds *(Lagenaria siceraria)* (Table 4) and either sell or give them away to others. A long season, difficult-to-grow crop, gourds are in high demand for making rattles, especially for children's gifts during ***Powamuyaw*** and ***Niman*** ceremonies. The rattles are also popular with tourists. Specific gourd forms have special ceremonial uses: rattles, musical instruments, decoration/costume, and water carriers. Gourd seeds, especially for the appropriate shapes, are not as

TABLE 5.—Farmers growing fruit trees.

Variety	% Farmers	n[2]
Hopi peach[3] ***(sipala)***	80%	39
Commercial peach[1,4] ***(sipala)***	25%	40
Hopi apricot ***(söhösipala)***	69%	39
Commercial apricot[1] ***(söhösipala)***	8%	39
Hopi pear ***(homi'sipala)***	18%	39
Commercial pear[1] ***(homi'sipala)***	13%	39
Hopi apple ***(mansaana)***	21%	38
Commercial apple[11],[5] ***(mansaana)***	29%	38
Hopi grape ***(oova)***	26%	39
Commercial grape[1] ***(oova)***	10%	39
Commercial plum[1,5] ***(palaspala)***	5%	40
Hopi almond ***(sipa'ltuva)***	5%	40
Commercial cherry[1]	3%	40
Commercial nectarine[1]	3%	40

[1]Non-Hopi variety or varieties.

[2]The number of farmers responding differs slightly for the different fruit tree varieties.

[3]Two or three varieties: cling, non-cling, yellow, white.

[4]Especially "Alberta."

[5]Two varieties.

readily available commercially as are those of many food crops. The greatest opportunity for obtaining seeds of new varieties is from the New Mexico Pueblos, and one farmer reported growing a dipper gourd from this source.

Dye plants.—The black seeded sunflower, ***(tceqa'a)*** *(Helianthus annuus)*, a unique Hopi variety, has been grown by the Hopi as a source of dark colored basketry and textile dye, and for medicinal purposes. Only six (12%) of those interviewed said they grow this distinct FV, while five (10%) grow commercial sunflowers.

One person said that ***komo*** *(Amaranthus cruentus)* was volunteering in her garden. This was commonly grown in the past, along with ***asafrani*** (safflower, *Carthamus tinctorius*) (Whiting 1939:74, 95), and used to color ***piki*** pink and yellow, respectively.

Fruit trees.—We were not able to determine the specific variety of fruit trees in many cases, and so the six Hopi and eight non-Hopi varieties listed often represent more than one variety each (Table 5). Some farmers had trees that were planted by their parents and were not sure of the variety, often just calling them the "old Hopi type." Most fruit trees are grown without irrigation and must be able to withstand strong winds. Old peach trees were the most commonly named fruit tree, and had the most recognized varieties. However there appears to be substantial experimentation with new species and varieties, often obtained from nurseries in Utah. In the past, Hopis split and sun-dried peaches for storage through the winter (Kennard 1979; Whiting 1939:79). Today this is rarely done

TABLE 6.—Garden vegetables grown by ho seholds with irrigated household gardens. Varieties Hopi unless otherwise indicated.

Variety	% Gardeners (n = 28)	Variety	% Gardeners (n = 28)
Chili *(tsiili)*	7%	Commercial cucumber[1]	14%
Commercial chili[1] *(tsiili)*	68%	Commerical pea[1]	7%
Commerical onion[1] *(siiwi)*	57%	Commerical carrot[1]	7%
Commerical tomato[1] *(tomaati)*	50%	Commercial lettuce[1]	7%
Commercial radish[1]	25%	Amaranth[1,3] *(komo)*	7%
Commercial cilantro[1,2] *(kora'nro, sila'ntro)*	14%	*Monarda menthaefolia*[3] *(nanakopsi)*	7%

[1]Non-Hopi variety or varieties.

[2]Hard to determine if Hopi variety exists; two gardeners planted purchased seeds, two obtained seed from family and/or had volunteer plants.

[3]All of these self-seeded.

according to the farmers we interviewed, although a few women said they make jams with the fruit.

Garden vegetables.—Hopi irrigated gardens include significantly greater numbers of new, non-Hopi crops and varieties than are grown in the dry-farmed fields (Table 6). Only two Hopi varieties were grown: chili and ***nanakopsi***. Chilis are by far the most important garden crop, while other garden crops appear to change significantly from year to year. Only two gardeners were growing Hopi chilis. Many of the respondents in this category were women in the farming households sampled in Hotevilla, which has a large, irrigated garden area (Soleri 1989).

The responses reported in Table 6 are only for vegetables which are grown using irrigation *and* which do not fit into other crop categories. For example, chilis are listed here but the string beans grown in gardens are included in Table 3 with dry-farmed string beans. This was done because the focus of this study is crop repertoires, not agricultural management practices.

DISCUSSION: CHANGING HOPI CROP REPERTOIRES

The Hopi, like most farmers and gardeners, enjoy experimenting with new crops or crop varieties. As new varieties are added to farmers' repertoires, old ones may be dropped. If retained long enough, new varieties become FVs through the process of evolutionary genetic change driven by biophysical and socio-cultural selection pressures.

During our field work, farmers frequently pointed out that commercial seeds are for irrigated agriculture. For some this was a reason not to try commercial seeds. Of the Hopi farmers interviewed who did experiment with commercial or ***Pahaana*** (Anglo) varieties for field agriculture, some explained that any seeds which grow successfully in their fields for more than two years "become Hopi."

That is, they adapt, and if desirable are adopted into the farmer's repertoire, at least for a while. This technique was mentioned by some in the case of commercial sweet corn, while others disagreed. At what point farmers begin thinking of a variety as "Hopi," i.e., at what point it becomes a FV subjectively, and what relation this has to genetic changes, is an important question that has rarely been investigated and is beyond the scope of our study.

We focused our questions on discovering the factors affecting farmers' decisions to adopt a new crop or variety, or drop an old one. It is likely that both environmental and sociocultural factors are important, but how these are balanced in the case of each crop or variety is unique. Zimmerer (1991), for example, found that Quechua farmers in the Peruvian Andes maintain diverse varieties of potatoes mainly for cultural reasons, and diverse varieties of corn mainly for production and consumption reasons. Hernández X. (1985) found in a study of corn in the greater southwest that diverse varieties are maintained by indigenous groups to meet a variety of ecological, consumption, and medicinal-ceremonial requirements, and suggested that color is used as an indicator of these characteristics.

In the following sections we first discuss the relevance of the 1935 crop survey to understanding change in crop repertoires. We then illustrate mechanisms of change with case studies of five crops: blue corn, sweet corn, beans, dye plants, and fruit trees, using cross sectional data from our survey and statements about change by the farmers.

Varieties named in 1935 and 1989.—It would be ideal to compare crop varieties in 1989 with those grown by the Hopis at an earlier date. Indeed, one of the inspirations of this research was the possibility of making such a comparison with the only survey of Hopi seeds that had been conducted. In 1935 ethnobotanist Albert Whiting and his colleagues, Volney Jones and Edmund Nequatewa, conducted this survey to find the source and distribution of Hopi farmers' crop seeds (Whiting 1935, 1937).

Whiting's seed source survey provides interesting insights into the agricultural crop repertoires of the farmers contacted, and the possible number of non-Hopi crops in those repertoires. However, neither of these topics was the focus of the survey, and no clear distinction was made between immediate source of seeds and the origin of the crop variety. The goal of the survey done by Whiting, Jones, and Nequatewa was to determine "seed source" "on the Reservation" and "off the Reservation," not Hopi vs non-Hopi nature of the seed, and there is a great deal of ambiguity in Whiting's typed field notes, which are apparently based on notes taken by Nequatewa, who did the actual interviewing. The 1935 seed source survey found that Hopi farmers in the sample obtained seeds from off the reservation in 33% of the cases. Seeds of many varieties obtained on-reservation are not identified with a Hopi varietal name, but only with adjectives such as "old" or "house," or "from Husband's family" or "from Moenkopi," or not further identified at all. A total of 619 "cases" of seed acquisition were reported, ranging from 16 for sweet corn and chili to 120 for beans (Whiting 1937).

The crop categories used by Whiting (1937) can be placed into two distinct groups: those crops for which the great majority of seeds were from an on-reservation source: corn (93%), beans (83%), squash and gourds (94%), chili (100%);

and fruit and vegetables for which seeds came from on-reservation sources in only half or less of the cases: melons (28%), fruit trees (51%), onions (13%), and vegetables (26%). This suggests that those crops of more ancient origin which are also more important in Hopi subsistence and culture were maintained through seed sources on the reservation. In comparison, crops which are more recent additions to the Hopi crop repertoire, have little if any significance in Hopi cultural tradition, and are not as important for subsistence, were more likely to be obtained from off-reservation sources.

Soon after we began our survey we realized that the seed "source" criteria used by Whiting in the 1935 survey is not a reliable indicator of whether or not seeds are Hopi. Seeds obtained on the reservation are not necessarily of Hopi crops, and now it is even possible to get seeds for Hopi crops from non-Hopi sources. For example, seeds for Hopi crops are now available commercially through groups like Native Seeds/SEARCH (Arizona), Seeds of Change (New Mexico), and others. A farmer may get commercial sweet corn or watermelon seeds from relatives and friends, and ***Kachinas*** distribute seed mixes which include non-Hopi varieties of crops including beans, melons, and sunflowers, as we observed in 1989. It is also quite possible that in 1935 non-Hopi seeds were being distributed by on-reservation sources such as relatives, friends, and ***Kachinas***.

Both the 1935 and 1989 surveys were of small, nonprobability samples of Hopi farmers. Therefore the only statement of comparison that can be made between the two surveys is that varieties named in both surveys were not lost to Hopi during the 54 years which separates them. This of course assumes that varietal names refer to the same FV at both times, since voucher specimens were not collected in either survey.

Table 7 compares the named varieties in the 1935 and 1989 surveys.[4] It is much more accurate for Hopi FVs than for non-Hopi varieties. We can see that 36 field crop and 5 fruit and vegetable FVs were named in both surveys and therefore were not lost. Of the 11 FVs named in 1935 and not in 1989, we can only say that it is possible (not probable) that they have been lost, and of the 16 FVs named in 1989 and not in 1935, we can only say that it is possible (not probable) that they have been reintroduced to Hopi farmers or have changed from non-Hopi to Hopi varieties in the intervening 54 years. This limited evidence suggests that there has been a high rate of retention of FVs over the last half century. The comparison of non-Hopi varieties suggests that they make up a large proportion of fruit and vegetable varieties and a small but increasing proportion of field crop varieties. The fact that a variety is still present does not mean that no loss of genetic diversity has occurred, since significant reductions in population size may be a source of loss.

Blue corn.—Hopi blue corn varieties can range in color from nearly black to a powdery grey color, depending on the pigmentation in the alleurone layer of the endosperm, or a combination of this and a red pericarp from mixing with ***kokoma.*** The existence of different varieties of blue corn was usually not mentioned until we asked specifically if there is more than one variety of Hopi blue corn. Of those who were asked this question (n = 39), 92% said there is more than one variety of Hopi blue corn. The varieties included "standard" blue ***(sakwaqa'ö),*** hard blue

TABLE 7.—Varieties named in the 1935 and 1989 surveys.

	1935 and 1989		1935 only		1989 only	
Crop	Hopi	non-Hopi	Hopi	non-Hopi	Hopi	non-Hopi
Field Crops						
Corn	13	1	2	3	5	3
Lima beans	3	0	0	0	1	1
String beans	3	1	0	0	0	0
Field beans	6	1	6	2	1	1
Tepary beans	1	0	0	0	1	0
Squash	2	1	0	0	1	5
Watermelons	2	0	0	0	0	2
Melons	1	3	1	1	2	0
Gourds	4	0	0	0	1	1
Dye plants	1	1	2	0	1	0
Total	36	8	10	6	13	13
Fruit Trees and Garden Vegetables						
Fruit trees	3	7	0	1	3	1
Garden vegetables	2	6	1	6	0	3
Total	5	13	1	7	3	4
Total All Crops	41	21	11	13	16	17

(huruskwapu), and grey-blue ***(maasiqa'ö).*** Table 2 shows the distribution of those varieties in the crop repertoires of farmers interviewed.

Despite the high proportion of farmers who recognize more than one variety of blue corn, 62% (31) grow only one variety, 34% (17) grow two, and only 4% (2) grow three blue corn varieties. While recognizing the different varieties some people added that they are now mixed together, especially ***sakwaqa'ö*** and ***maasiqa'ö.***

One possible reason for this mixing, or compression, of blue corn varieties may be that some of the attributes or shortcomings of particular varieties are no longer important. For example, because of its hard kernels ***huruskwapu*** was mentioned as being resistant to storage pests. However, an increasing use of commercially produced foods mean that today households no longer need to store a year's worth of harvest in case of crop failure, therefore storage problems are less important (Whiting 1939:11). Similarly, we were told by several interviewees that when all the grinding was done by hand women preferred using a lot of ***maasiqa'ö*** which is soft and easier to grind, even though it may not give as good a blue color to the food as ***sakwaqa'ö*** or ***huruskwapu.*** In the 1930s it appeared to Whiting that "the harder varieties of corn are being replaced by similar but softer varieties that are easier to grind" (Whiting 1939:11). Yet today virtually all grinding is done by machine, and this quality has lost its importance, according to those we spoke with.

The agronomic differences among these blue corn varieties could also affect farmer selection and would be an important avenue of investigation. Of those who responded to a question about which variety of corn which would do best in a dry year (n = 21), 29% said ***huruskwapu.*** Twenty-four percent said ***sakwaqa'ö*** would do best (one of those only recognized one blue corn variety), and 29% said both ***sakwaqa'ö*** and white corn did the best in dry years (one of those also only recognized one blue corn variety). ***Maasiqa'ö*** was never mentioned as a variety that is particularly good for dry conditions. Taking a different approach to drought adaptation, three farmers (14%) said that yellow corn ***(takuri)*** would probably do the best because it is "fast," that is it has a short growing season and therefore could produce a harvest before the stress of drought would affect it.

Kokoma, a dark red-purple corn whose ear is morphologically similar to ***sakwaqa'ö,*** is considered a part of the blue corn complex because it is used to enhance the blue color. The pericarp of ***kokoma*** is the source of its purple kernel color (Brown et al. 1952), and it has a characteristic red cob distinguishing it from other varieties with similar kernel color such as red corn ***(palakaö).*** Of the 18 people who reported growing ***kokoma,*** 33% of them use it as a planting admixture in ***sakwaqa'ö*** to deepen and enhance the blue corn's color.

Another factor which could be affecting the blue corn varieties in these Hopi farmers' repertoires is availability of seeds. Until recently, in the United States blue corn foods and seeds were only known and available in a few areas of the Southwest. For Hopi farmers wanting to experiment with new varieties of this important staple and ceremonial food crop the only sources of new genetic material were neighboring agricultural tribes, especially the New Mexico Pueblos and the Havasupai (Whiting 1939:67–68).

The current blue corn fad has been accompanied by a rise in seed companies selling blue corn seed. The availability of commercial blue corn seeds and blue cornmeal may have an effect on Hopi agriculture and social activities. And yet, 96% of the farmers interviewed reported growing Hopi white corn even though commercial white flour corn varieties are available, as is white corn meal. Combined with farmers' perception of Hopi white corn as drought hardy, as compared with non-Hopi white corn varieties, this suggests that environmental adaptation is one reason for retention of this crop, possibly in combination with culinary qualities and cultural meaning. Collins (1914a, 1914b) found evidence that Hopi and Navajo corn has been selected for adaptation to the local environment and traditional planting technique. He observed two unique morphological features: an elongated mesocotyl, allowing successful emergence from such a deep planting; and a dominant, deep radical, enabling the seedling to make use of moisture far below the soil surface.

Sweet corn.—Sweet corn is an extremely interesting crop in the Hopi farmer's repertoire for several reasons.

(1) Sweet corn ***(tawaktsi)*** is traditionally used in the ***Niman*** ceremony in July. ***Niman*** marks the beginning of the harvest and thus the return to the San Francisco Mountains of the spirits or ***Kachinas*** who assisted the agricultural cycle by bringing rain. This is one of the most important ceremonies of the year, especially in the eyes of children, who receive toys and other gifts, including sweet corn.

(2) Sweet corn is a very popular garden crop in the USA, grown by 34% of gardeners in 1986 (Bruce Butterfield, personal communication, 1991[5]). The popu-

TABLE 8.—Farmers growing Hopi and commercial sweet corn.

Description	All Farmers (n = 50) %	Without Moenkopi (n = 43) %	Moenkopi only (n = 7) %
Grow no sweet corn	24%	23%	29%
Hopi sweet corn	64%	70%	29%
Commercial sweet corn	50%	49%	57%
Only Hopi sweet corn	26%	28%	14%
Only commercial sweet corn	12%	7%	43%
Both Hopi and commercial	38%	42%	14%

larity of sweet corn as a garden crop is reflected in the many commercial varieties of seed available.

(3) The popularity of sweet corn as a food means that it is usually easy to find in some form year-round in most food stores, and at farmers' markets and road-side stands in season.

Sweet corn, therefore, differs from blue corn because both as seeds and as food it is readily available to Hopi consumers. Hopi farmers' crop repertoires appear to reflect the availability of commercial sweet corn and sweet corn seeds (Table 8). Unlike any other corn variety, half the farmers interviewed grow a commercial sweet corn variety. Yet, at the same time 64% continue to grow Hopi sweet corn. In addition, in spite of its ceremonial importance, 24% of those interviewed do not grow sweet corn. Many of them said that this is because sweet corn is easy to buy at irrigated Anglo farms near Winslow and Flagstaff.

Commercial sweet corn seems to be a satisfactory substitute for Hopi sweet corn, and many people remarked about the larger ear size and sweeter flavor of commercial varieties. Stalks of sweet corn with the ears still attached are used during the ***Niman*** and one astute Anglo farmer near Winslow has responded to this consumer demand by allowing Hopis to cut their own stalks in his field.

Seven out of the 10 farmers who were asked specifically about the difference between Hopi and commercial sweet corn varieties said that the commercial ones need more moisture. Of the remaining three, one described how he mixes seeds of Hopi sweet corn in with those of a commercial variety to make the commercial one better adapted. Another farmer said that if the commercial variety makes it through one year it will be alright and they will save the seeds. Although the third farmer had heard that commercial varieties "grow stronger" he only grows Hopi sweet corn.

Those who do grow a commercial sweet corn variety often said they put it in "good" (i.e., moist, fertile) fields. A number of farmers had stories of crop failure with commercial varieties, saying that those varieties will die in a bad year while Hopi sweet corn will produce something, even if the plant is stunted and drought stricken. Two farmers interviewed who now grow only Hopi sweet corn described a drastic deterioration in the quality of their crop each successive year after saving seeds from a commercial variety, perhaps because the commercial variety was a hybrid. However, as described above, some of the farmers growing commercial sweet corn say they save the seed and have done so for years, and others that they purchase the seed every year.

In spite of the small numbers, it is interesting to note the contrast between the farmers interviewed in irrigated Upper and Lower Moenkopi and farmers interviewed in the other dry-farmed villages (Table 8). In the two irrigated villages 43% grow only commercial sweet corn, while just 7% of the farmers we spoke with in the dry farmed villages grow only commercial sweet corn. At the same time, 70% of farmers interviewed in the dry farmed villages grow Hopi sweet corn, while only 29% do so in Upper and Lower Moenkopi. The obvious question is, are these results in some way related to the availability of irrigation water? While a larger, more in-depth survey is needed to assess this, these findings are suggestive of the influence of environmental constraints on crop repertoires. However, Moenkopi crop repertoires may also be a reflection of Hopi communities which are both physically and culturally closer to the dominant Anglo culture.

Carter (1945:57–58) said sweet corn was a relatively recent (approximately AD 1300) introduction to the Hopi crop repertoire. It is not as important as the flour corn varieties in Hopi culture. This may have facilitate its replacement with non-Hopi varieties when the opportunity arises.

Beans.—Like corn, beans (*Phaseolus* spp.) have been important both as a food crop and in ceremonies, most notably the ***Powamuyaw.*** The ***Powamuyaw*** is "a world renewal ceremony . . . to ready the children for initiation into the ***Kachina*** cult and encourage the cooperation of the ***Kachinas*** during the approaching growing season" (Mora 1979:36). During this winter ceremony lima beans are sprouted in the kivas to gauge how productive the coming season will be.

Pinto beans are similar to sweet corn in terms of seed and food availability. As with sweet corn it appears that widespread availability of seeds and food creates a complex dynamic between abandonment, retention, and elaboration of the crop variety in the farmers' repertoire. Sixteen farmers grow "Hopi" pintos. While many of these emphasized that their seeds were an old Hopi type, a number also noted that this variety has not always been a part of the Hopi farming system, as is suggested by the Hopi name ***Kastiil mori*** which means Mexican bean. Whiting (1939:83) identified a pinto ***Hubbell mori*** in the 1935 survey which was named after the trader who was said to have given the seed to the Hopis in the early 1930s. Nine farmers grow non-Hopi pintos and several of those explained how easy it is to find this seed (as food or feed) in grocery or feed stores or (as seed) in plant nurseries. Many respondents said they do not bother to grow pinto beans because they are so easy and inexpensive to buy.

Two older farmers (over 60 years old) whom we interviewed noted that yellow Hopi lima beans tend to dehisce easily when the pods are ripe, making them difficult to harvest. For those farmers this is the reason they no longer grow that lima bean variety.

Tsatsaymori is a Hopi name meaning "small beans" (Whiting 1939:80). Traditionally this referred to white tepary beans *(Phaseolus acutifolia)*, but also included black and mottled varieties, according to Whiting. The name describes a broad category and appears to be used today for any small field beans. During this survey ***tsatsaymori*** was used by informants to refer to samples of white teparies *(P. acutifolia)*, black beans *(P. vulgaris)*, and baby white limas *(P. lunatus)*.

When talking about ***tsatsaymori*** all interviewees mentioned how difficult it is to grow these beans because rabbits and grasshoppers eat the leaves so voraciously, implying that those pests prefer ***tsatsaymori*** leaves over those of other crops. It would be interesting to investigate whether all of the smaller-seeded beans are more vulnerable to grazing by rabbits and grasshoppers. Another possibility is that the reputation of teparies, described by Whiting as the "true" ***tsatsaymori***, is being transferred to other beans which are now included in the category ***tsatsaymori***.

Seven (14%) of the farmers we interviewed no longer grow ***tsatsaymori*** because the rabbit and grasshopper problem makes it too difficult to produce a good harvest. Several farmers described making a spray by steeping dog feces in water and spraying this on their plants, and one told us that he had to spray the plants every evening the last time he grew ***tsatsaymori*** several years ago.

Two of the households interviewed which are growing large amounts of ***tsatsaymori*** are both headed by an active husband and wife farming team, who are retired from their wage work and are now full-time farmers. In both cases ***tsatsaymori*** are purposefully grown in fields located near houses where more dogs are present, and it is easier to watch for and control rabbits. It may be that the amount of work necessary to produce a harvest is leading to the abandonment of this crop. This could be especially true as more and more Hopis must farm in their spare time while working full-time jobs outside the home.

Dye plants.—Dye plants appear to have been some of the most vulnerable to abandonment in the Hopi farming system, though to different degrees and for different reasons. In all cases they have been replaced by commercial chemical dyes.

Whiting (1939:95) cites Fewkes (1896) as saying that the Hopi obtained ***asafrani*** or safflower *(Carthamus tinctorius)* from the Mormons around 1870. ***Asafrani*** was traditionally cultivated in irrigated gardens by women who used it to color their ***piki*** bread. Several older women interviewed had grown this in the past or recalled their mothers growing it. They described going to the garden in the morning to harvest flower heads, and removing the yellow petals which were dried and then ground into a yellow powder. When added to white cornmeal batter it makes yellow ***piki***. Today commercial food dye is used instead. No one interviewed grows ***asafrani*** anymore, nor did they know of anyone growing it. It was mentioned that Moenkopi is the only place where it still might be found; however, none of the farmers interviewed for this survey in Upper or Lower Moenkopi reported growing ***asafrani***.

Red amaranth or ***komo*** *(Amaranthus cruentus)* was another traditional ***piki*** colorant also grown in irrigated gardens. *A. cruentus* is thought by some to be native to central and northern Arizona (NRC 1984:3), but the history of its use by the Hopi is not known. Whiting (1939:75) describes it as an introduced crop, whose red inflorescence was used to color ***piki*** a bright pink.

Many women and some men knew about ***komo***, far more than knew about ***asafrani***. No one interviewed was growing ***komo*** but two farmers said they have it volunteering in their fields. A few women said they saw some ***komo*** growing in a Hotevilla garden not long ago, but none was observed while conducting this survey.

Black seeded sunflowers (***tceqa'a***, *Helianthus annuus*) are a traditional Hopi FV whose black hulls produce a purple or black dye. Three people also described making a poultice from the hulls and/or seeds to use for eye medicine. Heiser (1945:165) noted that the hypocotyl of the black seeded Hopi sunflower "elongates much more rapidly" than in the common commercial Mammoth Russian variety, possibly representing an adaptation to the Hopi growing environment similar to that of the corn as described by Collins (1914a, 1914b). Only four interviewees said they still grow these sunflowers (two others said the sunflowers volunteer in their fields); however, there was great interest in acquiring the seeds. Perhaps the growing production of baskets for sale to tourists plays a role in this, especially as those buyers may be requesting "natural" or "traditional" craftwork.

Fruit trees.—There is concern about the decline and death of many of the old peach trees growing near the villages. Many old orchards consisting primarily of peaches and some apricots have been or are being abandoned. Competition from weeds for scarce soil moisture, broken, unpruned limbs, and roots exposed by wind erosion are the consequences of the neglect of these orchards, and can result in dead trees.

Although new varieties are available and being tried by Hopi households, some people we spoke with said that Hopi peach varieties produce sweeter fruit and are longer-lived and more drought resistant than commercial varieties. Several farmers described the continuing practice of starting Hopi peach and apricot trees from seed. The one problem noted with this technique is that it is relatively slow, especially when transplants several years old can be purchased in nearby towns.

CONCLUSION

Because ours was a nonprobability sample, it is not valid to extrapolate the results to Hopi farmers in general. Rather, we can suggest several hypotheses about Hopi crop diversity and change in general, based on the results of our survey, on other information available on the Hopi discussed above, and to some extent on a limited comparison with the 1935 survey. The general hypothesis is that while experimentation with new varieties appears to be constant in Hopi agriculture, the fate of each FV will depend on the unique combination of the biophysical and sociocultural selection environment of that FV. Below we present four more specific hypotheses illustrated with examples. The practical meanings of these hypotheses are well understood by many Hopi farmers, and it is they who should decide whether any further research to test them is appropriate.

(1) The biophysical environment. FVs will tend to be lost when changes in the local biophysical environment reduce the importance of the FVs' adaptation. FVs will tend to be retained when the biophysical environment remains the same, or

changes in ways that increase the importance of the FVs' adaptation. Water is a limiting factor for crop production in the Hopi environment. Where irrigation water is available it creates a controlled growing environment amenable to many crops and varieties, including MVs. For example, a much lower proportion of FVs are grown in the irrigated gardens than in rain-fed fields, and much more commercial sweet corn is grown in irrigated fields at Moenkopi than in the rain-fed fields elsewhere. Farmers frequently mentioned ecological differences between Hopi and non-Hopi varieties, and evidence exists for drought adapted root characteristics in Hopi corn and sunflower FVs.

(2) Sociocultural environment. FVs will tend to be lost when sociocultural changes, including acculturation, reduce the importance of their adaptation, especially when they do not have a central role in society and culture. FVs will tend to be retained when their role in culture and society is important, as with older crops such as beans and especially corn which are central in Hopi religion. It was common for farmers we interviewed to point out the importance of growing those varieties said to be given to the Hopi by their Creator. The introduction of grinding diminished the desirability of the softer blue corn ***(maasiquaë)***, while the cash economy reduced the desirability of the harder blue corns, since storing two years' harvest against harvest failure was no longer necessary. It may be that both of these factors helped lead to the partial collapse of blue corn varieties. In this example, blue corn is retained because it meets environmental conditions (drought, short season) and cultural requirements (for blue colored corn important in religious ceremonies), but different varieties of blue corn are being lost because the importance of their unique postharvest characteristics is much diminished by social changes. Hopi tepary bean FVs may be being lost because social changes mean that people no longer have the time to spend in the field protecting them from predators.

When biophysical and sociocultural changes make possible the replacement of FVs, two other factors determine the fate of FVs in farmers' repertoires:

(3) Availability of seeds. FVs will tend to be lost when seed of new varieties that are similar (including MVs) become available, as with sweet corn, where widespread availability of commercial seed has been associated with a decrease in Hopi farmers growing Hopi sweetcorn FVs. There are increasing opportunities for Hopis to buy seeds of non-Hopi varieties that are similar to Hopi FVs. For example, the larger proportion of farmers in 1989 growing commercial varieties of red vs. yellow watermelon may reflect differences in seed availability. However, while seed for blue corn or blue corn food products have not been commercially available until recently, white corn seed and food products have been available for some time, and yet the Hopi white corn FV has been retained, supporting the idea that availability of seeds is not the only important factor in the retention of corn FVs. Many farmers mentioned the availability of pinto beans for food (and seed) as a reason for not growing them. Pintos are an historic introduction and are not as important in Hopi culture as other bean FVs.

(4) Availability of alternative products. FVs will tend to lost when alternative products become available. For example, the dye plants safflower and red amaranth, used to color ***piki*** bread and other products, were lost when cheap commercial food dyes became available. The keeping qualities of Hopi watermelon FVs may

no longer be a factor favoring their retention when watermelon or other fruits are available in stores year-round.

As the importance of stability and diversity for the sustainability of agriculture becomes more widely accepted, the ability of FVs to produce relatively stable yields with low inputs in the local environments in which they have been selected may also become more important. This could lead to increasing respect for diverse local cultural groups and their knowledge about creating and maintaining crop genetic diversity. The Hopi people today live in the midst of the United States, one of the nations most committed to the industrialization of agriculture, including the use of MVs. Their retention of a large proportion of their FVs may therefore hold important lessons for the maintenance of crop genetic diversity. Conservation of this diversity may best be accomplished in the long run by ensuring its survival *in situ* as part of local farming communities like the Hopi.

NOTES

[1]Total farmers equals 45 because ages of five farmers were not estimated.

[2]Spelling of Hopi words in this paper is based on Albert and Shaul (1985), or when not found in that reference, on Whiting (1939).

[3]The original notes are at the University of Michigan, Museum of Anthropology, Ann Arbor, MI 48109-1079, and we obtained copies from the Director, Richard I. Ford. There are a total of 59 survey records of 1–2 pages each; 56 surveys of Hopi and 3 of Navajo farmers. Their survey included "all of the households" in Shipaulovi and "typical families" from all of the other villages, including Moenkopi (Whiting 1935:2). Only data from 46 were reported, however, "the others being considered unsuitable for this purpose" (Whiting 1937:13). No basis is given for eliminating the other 10 surveys. They established their headquarters in October and made a collection of the crop plants "which were mature at that season" (Whiting 1935:1). It is not clear what relation the specimens had to the interviews about seed sources, since Whiting states that "in addition to the actual collection of crop specimens a survey was taken of over fifty households" (Whiting 1935:2). It appears as though Nequatewa, a Hopi who worked at the Museum of Northern Arizona, did most of the actual field work, as Whiting writes that he "could be depended on to carry on the investigation in the homes of his own people without the ever constant disturbing element of two, somewhat eccentric white ethnologists" (Whiting 1935:1). No other information is available on the methods used in the 1935 survey.

[4]We used 55 of Whiting's 56 Hopi survey forms. We eliminated one because it was based on the entire farming career of a man who no longer farmed, while the other surveys apparently contain information only for seeds of crops harvested in 1935.

[5]Bruce Butterfield is the director of research for the National Gardening Association in Burlington, Vermont. Each year they publish the National Gardening Survey based on research by the Gallup Organization. Every fifth year this includes information on crop varieties grown.

ACKNOWLEDGEMENTS

We thank the many Hopi farmers and others who patiently assisted us in this research. Walter Hamana helped us identify active farmers as well as giving us a taste of what Hopi farming is like in his bean field. Joyce and Morgan Saufkie helped answer questions and suggested contacts in their village and gave us some fine samples of Hopi corn varieties.

Pat Dallas and Dennis Gebhardt, both formerly with the Office of Hopi Lands, were supportive throughout the project. The Museum of Northern Arizona's research library and Whiting's archives in the care of David Seaman, were both valuable resources for background information. Sandra Dunavan and Richard Ford of the Museum of Anthropology, University of Michigan, Ann Arbor sent Alfred Whiting's notes from the 1935 survey.

Gary P. Nabhan at Native Seeds/SEARCH (NS/S) first had the idea for research on changing Hopi crop repertoires and acquired the funding for this research. He also conducted the interviews at Upper and Lower Moenkopi. We carried out this research as employees of NS/S. Other NS/S staff made this work easier with their assistance in preparing seed orders, discussing crop varieties, and the financial management of this project. We thank the editor, Deborah Pearsall and the reviewers for the *Journal of Ethnobiology* (Stephen Brush and one anonymous reviewer) for their comments on a draft of this article. Thanks to José Luna-Ruiz for the Spanish and Kebe Brahim for the French translations of the abstract.

Finally, we thank the Pioneer Education Foundation for the financial support for the project which made this research possible. This paper is based on the final report of the project (Soleri and Cleveland 1989) and a paper presented by Soleri (1990) at the Society of Ethnobiology meeting in Tempe, Arizona. As authors we alone are responsible for the contents of this article.

LITERATURE CITED

ALBERT, ROY and DAVID LEEDOM SHAUL (compilers). 1985. A Concise Hopi and English Lexicon. John Benjamins Publishing Company, PHILADELPHIA.

ALTIERI, MIGUEL. 1988. Rethinking crop genetic resource conservation: A view from the South. Conservation Biology 3:77–79.

ANDERSON, JOCK R. and PETER B.R. HAZELL. 1989. Synthesis and needs in agricultural production. Pp. 339–356 *in* Variability in Grain Yields: Implications for Agricultural Research and Policy in Developing Countries. Jock R. Anderson and Peter B.R. Hazell (editors). Johns Hopkins University Press, Baltimore.

ARIZONA STATE DATA CENTER. 1992. Census of Population. Arizona State Data Center, Population Statistics Unit, Department of Economic Security, Phoenix.

BARKER, RANDOLPH, ERIC C. GABLER, and DONALD WINKELMANN. 1981. Long-term consequences of technological change on crop yield stability: The case for cereal grain. Pp. 53–78 *in* Food Security for Developing Countries. Alberto Valdés (editor). Westview, Boulder.

BOROJEVIC, SLAVKO. 1990. Principles and Methods of Plant Breeding. Elsevier, Amsterdam.

BRADFIELD, MAITLAND. 1971. The changing pattern of Hopi agriculture. Royal Anthropological Institute Occasional Paper No. 30, Royal Anthropological Institute of Great Britain and Ireland, London.

BRADY, NYLE C. 1974. The Nature and Properties of Soils. Eighth Edition. Macmillan Publishing Company, New York.

BREW, J.O. 1979. Hopi prehistory and history to 1850. Pp. 514–523 *in* Handbook of North American Indians, Volume 9, Southwest. Alfonso Ortiz (editor). Smithsonian Institution Press, Washington, D.C.

BROWN, A.H.D. 1978. Isozymes, plant population genetic structure, and genetic conservation. Theoretical and Applied Genetics 52:145–157.

BROWN, LESTER R. 1990. The illusion of progress. Pp. 3–16 *in* Lester R. Brown et al.: State of the World 1990. Norton, New York.

BROWN, WILLIAM L., E.G. ANDERSON, and ROY TUCHAWENA, JR. 1952. Observations on three varieties of Hopi maize. American Journal of Botany 39:597–609.

BRUSH, STEPHEN B. 1989. Rethinking

crop genetic resource conservation. Conservation Biology 3:19–29.

__________. 1991. A farmer-based approach to conserving crop germplasm. Economic Botany 45:153–165.

__________, MAURICIO BELLON CORRALES, and ELLA SCHMIDT. 1988. Agricultural development and maize diversity in Mexico. Human Ecology 16:307–328.

CARTER, GEORGE. 1945. Plant Geography and Culture History in the American Southwest. Viking Fund Publications in Anthropology, No. 5, New York.

CLAWSON, DAVID L. 1985. Harvest security and intraspecific diversity in traditional tropical agriculture. Economic Botany 39:56–67.

CLEVELAND, DAVID A. and DANIELA SOLERI. 1991. Food from Dryland Gardens: An Ecological, Nutritional, and Social Approach to Small-scale Household Food Production. Center for People, Food, and Environment, Tucson, Arizona.

COLLINS, G.N. 1914a. Pueblo Indian maize breeding. Journal of Heredity 5:255–268.

__________. 1914b. A drought-resisting adaptation in seedlings of Hopi maize. Journal of Agricultural Research 1:293–302.

COOPER, DAVID, RENÉE VELLVÉ, and HENK HOBBELINK (editors). 1992. Growing Diversity: Genetic Resources and Local Food Security. Intermediate Technology Publications, London.

EHRLICH, PAUL R. and EDWARD O. WILSON. 1991. Biodiversity studies: Science and policy. Science 253:758–762.

FEWKES, J. WALTER. 1896. A contribution to ethnobotany. American Anthropologist (Old Series) 9:14–21.

FORD, RICHARD I. 1981. Gardening and farming before A.D. 1000: Patterns of prehistoric cultivation north of Mexico. Journal of Ethnobiology 1:6–27.

FRANKEL, OTTO H., and MICHAEL E. SOULÉ. 1981. Conservation and Evolution. Cambridge University Press, Cambridge.

FRIGOUT, ARLETTE. 1979. Hopi ceremonial organization. Pp. 564–576 *in* Handbook of North American Indians, Volume 9, Southwest. Alfonso Ortiz (editor). Smithsonian Institution Press, Washington, D.C.

HACK, JOHN T. 1942. The Changing Physical Environment of the Hopi Indians of Arizona. Reports of the Awatovi Expedition, Report No. 1, Peabody Museum, Harvard University, Cambridge.

HARLAN, JACK R. 1992. Crops and man. Second Edition. American Society of Agronomy, Crop Science Society of America, Madison, Wisconsin.

HEISER, CHARLES B. 1945. The Hopi sunflower. Missouri Botanical Garden Bulletin 33:163–166.

HERNÁNDEZ XOLOCOTZI, EFRAIM. 1985. Maize and man in the greater Southwest. Economic Botany 39:416–430.

HIEB, LOUIS A. 1979. Hopi world view. Pp. 577–580 *in* Handbook of North American Indians, Volume 9, Southwest. Alfonso Ortiz (editor). Smithsonian Institution Press, Washington, D.C.

HOPI TRIBE. 1987. Hopi-Tunatya. Hopi Comprehensive Development Plan. A Summary. Hopi Tribe, Kykotsmovi, Arizona.

KENNARD, EDWARD A. 1979. Hopi economy and subsistence. Pp. 554–563 *in* Handbook of North American Indians, Volume 9, Southwest. Alfonso Ortiz (editor). Smithsonian Institution Press, Washington, D.C.

KEYSTONE. 1990. Final Consensus Report of the Keystone International Dialogue Series on Plant Genetic Resources. Madras Plenary Session, Genetic Resources Communications Systems, Washington, D.C.

__________. 1991. Final Consensus Report: Global Initiative for the Security and Sustainable Use of Plant Genetic Resources. Keystone International Dialogue Series on Plant Genetic Resources. Oslo Plenary Session, Genetic Resources Communications Systems, Washington, D.C.

MORA, JOSEPH. 1979. The Year of the Hopi: Paintings and Photographs by 1904–1906. Rizzoli International Publications, New York.

NATIONAL RESEARCH COUNCIL. 1984. Amaranth: Modern Prospects for an Ancient Crop. National Academy Press, Washington, D.C.

__________. 1989. Alternative Agriculture. National Academy Press, Washington, D.C.

NEQUATEWA, EDMUND. 1967. Truth of a Hopi: Stories Related to the Origin, Myths, and Clan Histories of the Hopi. Northland Press, Flagstaff, Arizona. Originally published in 1936 as Bulletin No. 8, Museum of Northern Arizona.

OLDFIELD, MARGERY L. and JANICE B. ALCORN. 1987. Conservation of traditional agroecosystems. Bioscience 37:199–208.

PIMENTEL, DAVID, ULRICH STACHOW, DAVID A. TAKACS, HANS W. BRUBAKER, AMY R. DUMAS, JOHN J. MEANEY, JOHN A.S. O'NEAL, DOUGLAS E. ONSI, and DAVID B. CORZILIUS. 1992. Conserving biological diversity in agricultural/forestry systems. Bioscience 42:354–362.

PLUCKNETT, DONALD L., NIGEL J.H. SMITH, J.T. WILLIAMS and N. MURTHI ANISHETTY. 1987. Gene Banks and the World's Food. Princeton University Press, Princeton, New Jersey.

PREVOST, DEBORAH, ROBERT J. AHRENS, and DAVID M. KRIZ. 1984. Traditional Hopi agricultural methods. Journal of Soil and Water Conservation 39:170–171.

REIDHEAD, VAN A. 1989. An integrated methodology for research with urban American Indians. Cultural Anthropology Methods 1:8–10.

RICHARDS, PAUL. 1986. Coping with Hunger: Hazard and Experiment in an African Rice-farming System. Allen and Unwin, London.

SOLERI, DANIELA. 1989. Hopi gardens. Arid Lands Newsletter 29:11–14. Office of Arid Land Studies, University of Arizona, Tucson.

__________. 1990. A preliminary survey of Hopi crop repertoires and implications for in situ conservation of crop genetic resources. Paper presented at the 13th Annual Meeting of the Society of Ethnobiology, Tempe, Arizona.

__________ and DAVID. A. CLEVELAND. 1989. Hopi Crop Diversity and Change: A Report on a Preliminary Survey of Hopi Crop Genetic Resources. Project Report of Sources of Seed in a Native American Farming Tradition: Hopi Crops After A Half Century of Culture Change. Native Seeds/SEARCH, Tucson.

__________ and STEVEN E. SMITH. 1991. Seedbanking as a famine mitigation strategy. Pp. 93–103 *in* Famine Mitigation. Proceedings of Workshops held in Tucson, Arizona and Berkeley Springs, West Virginia. Office of Arid Lands Studies, University of Arizona, Tucson.

STEPHEN, ALEXANDER M. 1936. Hopi Journal of Alexander M. Stephen. Vol. 1. Elsie C. Parsons (editor). Columbia University Contributions to Anthropology 23, Columbia University Press, New York.

THURSTON, H. DAVID. 1992. Sustainable Practices for Plant Disease Management in Traditional Farming Systems. Westview Press, Boulder, CO.

WEITZIEN, E. and G. FISCHBECK. 1990. Performance and variability of local barley landraces in Near Eastern environments. Plant Breeding 104:58–67.

WHITING, ALFRED F. 1935. A Hopi crop survey: Preliminary report. Unpublished manuscript in the Whiting Archives, Flagstaff, Arizona.

__________. 1936. Hopi Indian agriculture: I. Background. Museum of Northern Arizona Museum Notes: 8(10).

__________. 1937. Hopi Indian agriculture II. Seed source and distribution. Museum of Northern Arizona Museum Notes: 10(5):13–16.

__________. 1939. Ethnobotany of the Hopi: Museum of Northern Arizona Bulletin No. 15, Northern Arizona Society of Science and Art, Flagstaff.

WILKES, GARRISON. 1989. Germplasm preservation: Objectives and needs. Pp. 13–41 *in* Biotic Diversity and Germplasm Conservation, Global Imperatives. Lloyd Knutson and Allan K. Stoner (editors). Kluwer Academic Publishers, Dordrecht, Netherlands.

ZIMMERER, KARL S. 1991. Managing diversity in potato and maize fields of the Peruvian Andes. Journal of Ethnobiology 11:23–49.